Capacitor Theory

Any arrangement of **two conductors** separated by an **electric insulator** (i.e., **dielectric**) is a capacitor. An electric charge deposited on one of the conductors induces an equal charge of opposite polarity on the other conductor. As a result, an electric field exists between the two conductor surfaces and there is a potential difference between them. The electric field anywhere between the conductor surfaces is directly proportional to the magnitude of the charge Q on the conductors. And the potential difference V is also directly proportional to the **charge Q**. The ratio Q/V is thus a constant for any electric field distribution as determined by the shape of the conductors, the distance of separation, and the dielectric in which the field exists.

The ratio Q/V is called the capacitance, **C**, of a particular arrangement of conductors and dielectric. Thus, **C = Q/V**, where Q and V are in units of coulomb and volt. C has the units farad (F).

$$C = \frac{\varepsilon_r \ \varepsilon_o \ A}{d} \quad (F) \qquad (farads)$$

The simple theoretical expression for the capacitance value of a parallel plate capacitor is where

A	=	plate area [m^2] = cross section of electric field,
d	=	distance between plates [m],
ϵ_o	=	permittivity of free space = 8.854 x 10^{-12} F/m and
ϵ_r	=	relative permittivity of the dielectric between the plates [dimension less].

This calculated value is based on the assumption that the charge density on the plates is uniformly distributed. In practice there is always a concentration of charge along the edges. This charge concentration is at the sharp corners of the plates. Thus for a given voltage, the actual total charge is always greater than the theoretical total charge.

Practical Capacitor Model

The low frequency lossy model is introduced to allow you to measure capacitance with a capacitance measuring bridge instrument.
Discrete component measurements and models of the physical capacitor need to be considered here. Consideration of a finite subdivision of the physical device may assist in arriving at a lumped discrete equivalent circuit model of the practical physical device (ie: a capacitor).

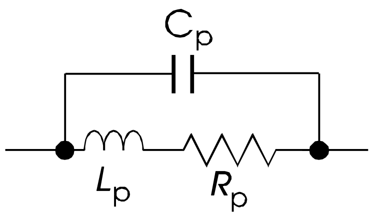

Figure 1.
Capacitor Model
With Parasitic L & R

First consider the physical device, the capacitor. We have two conducting surfaces separated by some distance. Hence a defined **capacitor**. Assume there is a voltage applied to the capacitor. The dielectric has some **loss**[1] and will conduct a small current. One can consider this as a distributed loss within the length of the dielectric material between the two conductors. Hence a **resistance** in parallel with the capacitor.The lossy dielectric has length. Hence one could conceive a distributed **inductance**[2] in series with the distributed resistance. Hence the inductor as shown in figure 1.

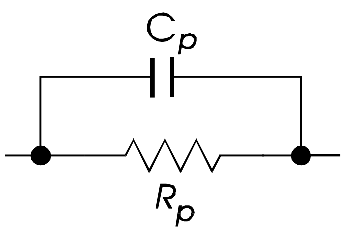

Figure 2. Capacitor Model With R Only

At very low frequencies (say 1 kHz) the parasitic **inductance can be ignored**[3] **for the parallel plate capacitor** you will be using. Hence the model will only have the capacitor and resistor in parallel as seen in figure 2.

In this experiment the parallel model resistance is very large. Hence the dissipation of energy is small. The resistor will dissipate very little energy. Thus we will have a capacitor with a low dissipation factor, **D**. One can calculate the resistance value knowing the value of D measured after balancing the bridge.

The capacitance measuring bridge has to be adjusted so that both the capacitance and the

[1] The dielectric has a finite resistivity, so when an electric field is across it, a small but finite electric current flows through it. This current, or charge flow, is referred to as a loss (from what an ideal device would do).

[2] Because the plates of the capacitor are conductors with current flowing through them, they have a small amount of self inductance.

[3] The change in current and direction is so slow, the self inductance effect is almost too small to measure.

resistance of the practical model are balanced. This is the reason for adjusting both the CRL and the DQ dials of the Capacitance Measuring Bridge.